SYSTEM-WIDE SIGNIFICANCE OF PREDATION ON JUVENILE SALMONIDS IN THE COLUMBIA AND SNAKE RIVER RESERVOIRS

Annual Report of Research

1991

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Project No. 90-078

Contract No. DE-AI79-90BP07096

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ABSTRACT

We indexed consumption rates of northern squawfish (Ptvchocheilus oresonensis) preying upon juvenile salmonids in four lower Snake River reservoirs (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite) and John Day Reservoir, Columbia River, in 1991. We captured a total of 2118 northern squawfish at Snake River locations from April to June and 297 in John Day Reservoir during May and July. Catches of northern squawfish were highest within the boat restricted zone (BRZ) of dam tailrace areas. Stomach contents were also collected from smallmouth bass (Micropterus dolomieui), channel catfish (Ictaluris ounctatus), and walleye (Stizostedion vitreum).

A total of 1408 northern squawfish digestive tracts were analyzed and the overall diet (% weight) was dominated by fish and crustaceans (55% and 26%, respectively). On average, northern squawfish contained 0.63 salmonids$\cdot$fish^{-1}, and northern squawfish collected in BRZs contained significantly more salmonids (0.83 salmonids$\cdot$fish^{-1}) than those collected in non-restricted zones (0.53 salmonids$\cdot$fish^{-1}; $P < 0.001$). We also analyzed stomach contents of 1145 smallmouth bass. Crustaceans (primarily crayfish) dominated the diets of smallmouth bass (64%) followed by fish (27%). Overall, the consumption rate of juvenile salmonids by smallmouth bass was low (0.01 salmonids$\cdot$fish$^{-1}\cdot$day^{-1}).

The northern squawfish consumption index (CI) at Snake River locations ranged from zero at all mid-reservoir locations to 1.2 at Lower Granite forebay. In John Day Reservoir, CI values ranged from 0.5 to 1.9 in May and from 0.9 to 3.0 in July. Consumption index values were highest in forebay and tailrace areas, and were slightly higher in BRZs than in non-restricted zones. Efforts to conduct CI sampling during high juvenile salmonid densities were

successful at most locations except at Lower Monumental Dam. Low water temperatures at Snake River locations (range 6-13" C) may have contributed to the low CI values. Mean CI values were lower in the Snake River locations compared to Columbia River locations from the spring sampling period when water temperatures and species of salmonids migrating are similar (x CI=0.5 and 1.3, respectively).

Work continued on a northern squawfish bioenergetics index to complement the CI. Fish in two age-groups, <5 and 6 yrs, showed the largest percent weight change during the growth season (36% and 24%, respectively), while fish in older age-groups displayed no significant seasonal growth. Analysis of age and growth information indicated that relatively large sample sizes of aged northern squawfish would be needed to detect small changes in growth. An alternative growth approach examining changes in mean predator weight distributions over the growing season was also explored.

The CI data will be integrated with predator abundance index data estimated by Oregon Department of Fish and Wildlife to derive an index of juvenile salmonid predation by northern squawfish in Snake River reservoirs. Also, work will continue on a bioenergetics model to be used in combination with the CI.

ACKNOWLEDGEMENTS

We gratefully acknowledge Bill Nelson, Alec Maule, Steve Vigg, and Craig Tuss for their helpful review comments on an earlier draft of this report. Sampling coordination was facilitated by the Fish Passage Center, particularly Margaret Filardo, whom we thank. We also thank Bill Maslen, the Bonneville Power Administration contract officer, for his assistance during the study.

INTRODUCTION

The U.S. Fish and Wildlife Service (FWS) and the Oregon Department of Fish and Wildlife (ODFW) recently completed a six year study to determine the significance of predation on juvenile salmonids in John Day Reservoir (Poe and Rieman 1988). Estimates of juvenile salmonid losses to predators indicated that predation may account for the majority of previously unexplained losses of juvenile salmonids in John Day Reservoir (Rieman et al. 1991). Continuing need for predation research has been designated as high priority by several regional committees and agencies including: (1) the Northwest Power Planning Council (section 403(d) (1) of the 1987 Columbia River Basin Fish and Wildlife Program and in September 1991 proposed amendments to this program); (2) the Water Budget Evaluation - Reservoir Mortality Technical Work Group (minutes of January 27, 1989 meeting); and (3) the 1989 Predator-Prey Modeling Workshop (Fickeisen et al.. 1990).

Although predation on juvenile salmonids was significant in John Day Reservoir, we do not know the relative significance of predation as a mortality factor in other Columbia and Snake river reservoirs. Because predation management is an ongoing program (Nigro 1990), we also need to: (1) establish baseline data on predator abundance and consumption rates in other reservoirs to evaluate the effectiveness of predation management actions; (2) determine where predation management actions should be implemented; and (3) further develop and refine predation models to help evaluate predation management and to predict cumulative impacts of predators on juvenile salmonid survival throughout the system.

In 1989 a collaborative study of the FWS and ODFW was initiated to develop a predation index to estimate the relative magnitude of juvenile salmonid losses to predators in reservoirs throughout the Columbia River Basin. Development of the index was completed in 1990 and detailed descriptions of the analytical, field, and laboratory techniques for a consumption index for northern squawfish (Ptvchocheilus oreqonensis) may be found in Petersen et al. (1990); corresponding methods for abundance indexing may be found in Vigg and Burley (1990).

In 1990 the consumption of juvenile salmonids by predators, primarily northern squawfish, were indexed in four lower Columbia River reservoirs (Bonneville, The Dalles, John Day, and McNary) and results are reported in Petersen et al. (1991). This report presents the results of indexing northern squawfish consumption rates upon out-migrating juvenile salmonids in four reservoirs in the lower Snake River and John Day Reservoir of the Columbia River during 1991.

METHODS

Field Methods

Field sampling in 1991 was completed within the Snake River at 14 locations from Ice Harbor Dam forebay to about 250 meters above the confluence of the Snake and Grande Ronde rivers (Figure 1, Table 1). Sampling was also conducted in the lower portion of the Clearwater River near the city of Lewiston, Idaho. Also, John Day Reservoir on the Columbia River was sampled during the spring (May) and summer (July) out-migration of juvenile salmonids to provide data to account for inter-annual trends (Petersen et al. 1991; Figure 2). Timing of sampling location? was designed to coincide with major hatchery releases and increased juvenile salmonid abundance at hydroelectric dams.

For each reservoir, the naming and sampling of locations followed the methodology of Petersen et al. (1991). To assist interpretation of results, a typical hydro-electric facility is shown in Figure 3 that displays the positioning of transects within tailrace and forebay boat restricted zones (BRZs).

Dam, or project, operations were adjusted to allow sampling within the BRZs and around ice trash sluiceways, spillgates, and powerhouse outflows. Sampling was conducted immediately after project operation change, therefore gut contents of captured predators should reflect conditions of typical project operation.

Two 18-foot Smith Root[1] electrofishing boats were used to capture

[1]Mention of brand name does not constitute endorsement by the U.S. Government.

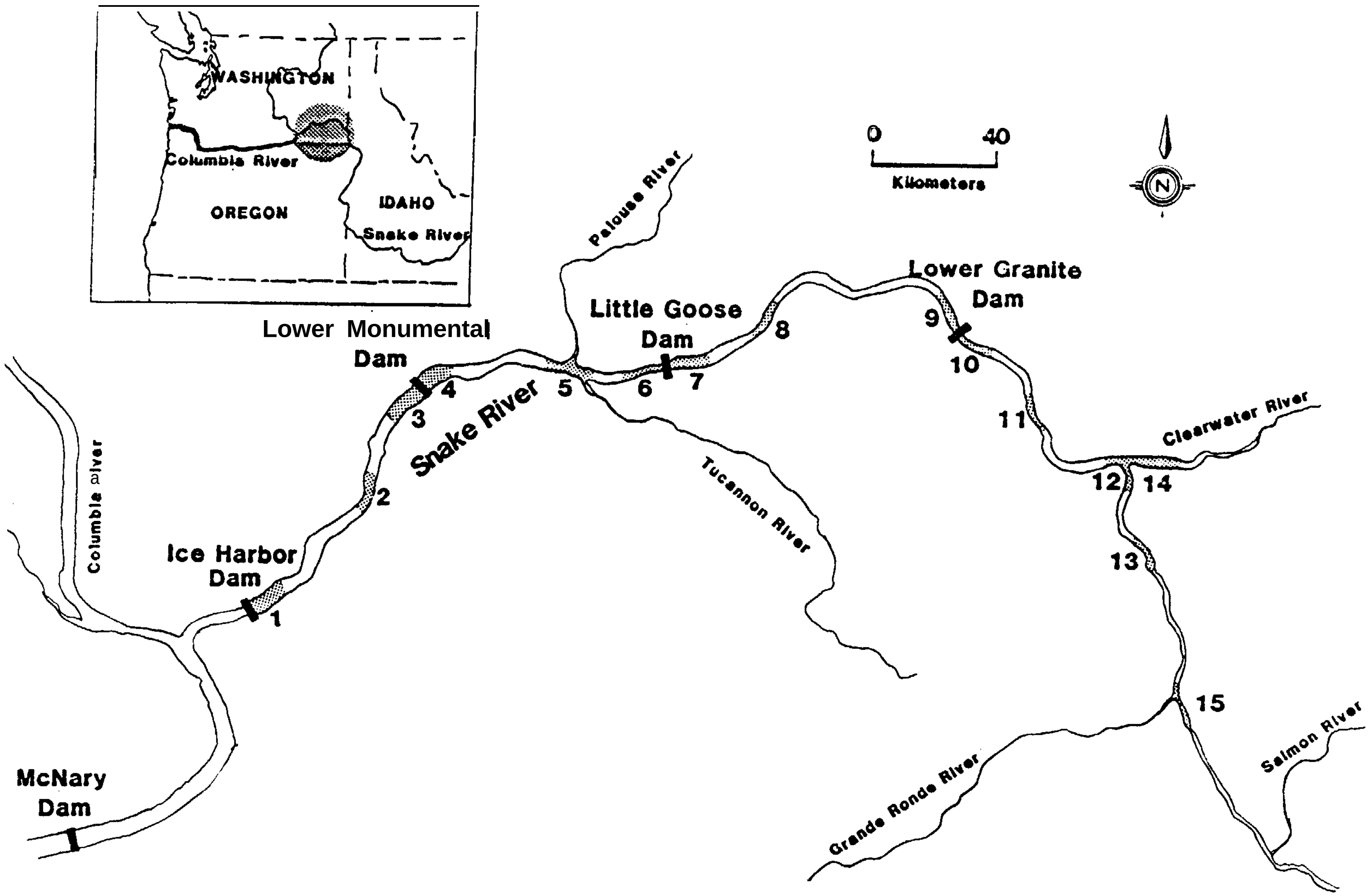

Figure 1. Sampling locations on the Snake River (shaded areas) for consumption Indexing during 1991. Location numbers concide to Table 1.

Table 1. Sampling locations and dates for northern squawfish consumption indexing during 1991. Fb=Forebay, Mr=Mid-reservoir, Tr=Tailrace, Up=Upper reservoir.

RESERVOIR Location	RIVER KILOMETER	DATES SAMPLED	
Snake River			
ICE HARBOR			
1. Ice Harbor Fb	16-23	5/14-5/15	5/30-5/31
2. Ice Harbor Mr	28-39	5/9-5/10	5/28-5/29
3. Lower Monumental Tr	60-67	5/9-5/10	5/31-6/1
LOWER MONUMENTAL			
4. Lower Monumental Fb	67-72	5/7-5/8	5/29-5/30
5. Lower Monumental Mr	92-100	5/7-5/8	5/23-5/24
6. Little Goose Tr	105-112	5/2-5/3	5/23-5/24
LITTLE GOOSE			
7. Little Goose Fb	112-120	5/2-5/3	5/21-5/22
8. Little Goose Mr	128-136	4/30-5/1	5/21-5/22
9. Lower Granite Tr	165-172	4/18-4/19	4/27-4/29
LOWER GRANITE			
10. Lower Granite Fb	172-180	4/16-4/17	4/26,4/28
11. Lower Granite Mr	185-196	4/11-4/12	4/25-4/26
12. Lower Granite Up	219-228	4/3,4/5	4/10,4/12
13. Asotin	229-238	4/9-4/10	4/23-4/24
14. Clearwater R.	0-6	4/2,4/4	4/9,4/11
FREEFLOWING RIVER			
15. Rogersburg	268-276	4/5-4/6	4/16,4/19
Columbia River			
JOHN DAY			
16. John Day Fb	347-353	5/16-5/17	7/11-7/12
17. John Day Mr	387-395	5/15,5/21	7/11-7/12
18. McNary Tr	459-468	5/16-5/17	7/9-7/10

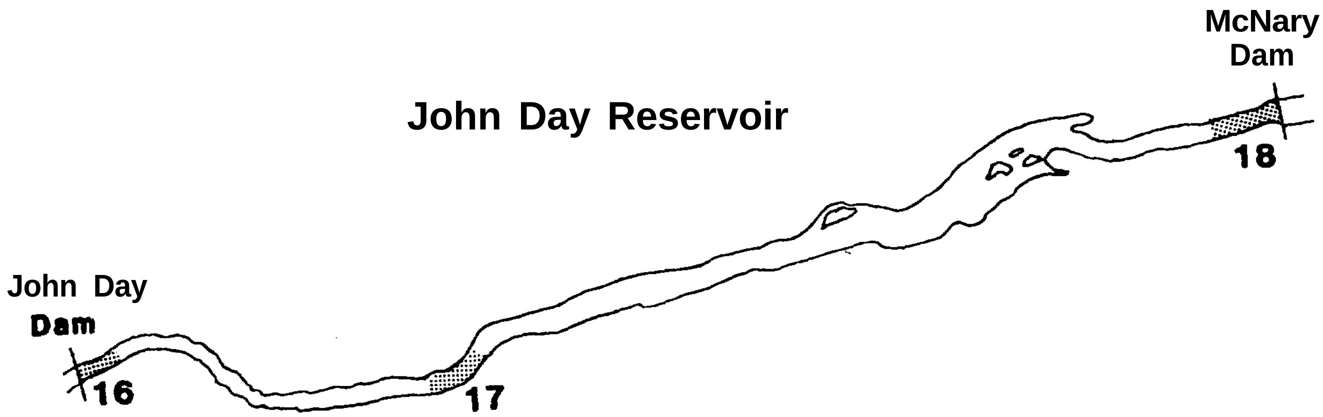

Figure 2. Sampling locations for John Day Reservoir during 1991 northern squawfish Consumption Indexing.

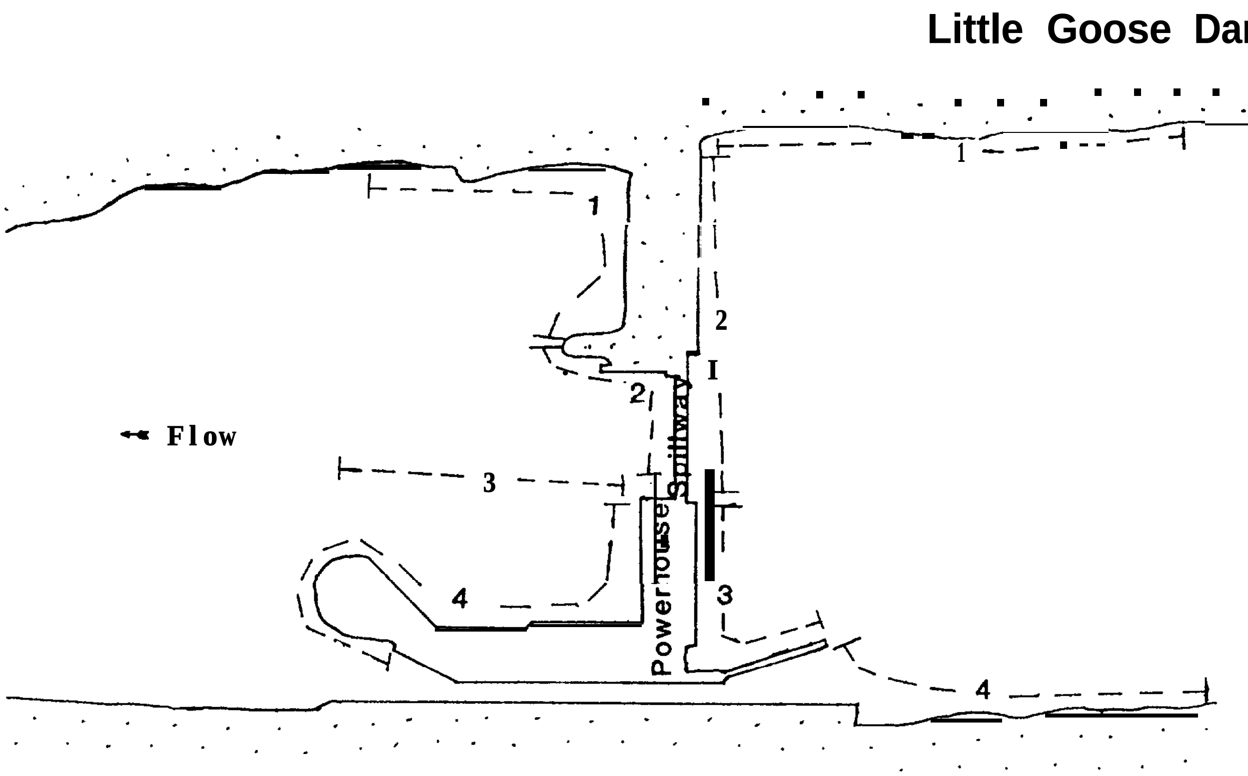

Figure 3. An example of typical sample locations within the Boat Restricted Zone (BRZ) of a dam.

predators. Transects were electrofished for 15 minutes and the first six transects each day were chosen at random. In forebay and tailrace locations, two of the six random transects were from BRZs. Additional, discretionary transects were sampled to maximize catch of northern squawfish. A minimum target catch of 30 northern squawfish per day at each location was established (Petersen et al. 1990); however, around dams the minimum target catch was split into two units; 15 per day in the BRZ and 15 per day outside the BRZ. Sampling commenced 90 min before sunrise at all locations. Target predators were northern squawfish, smallmouth bass (Micropterus dolomieui), channel catfish (Ictalurus punctatus), and walleye (Stizostedion vitreum). Northern squawfish were killed soon after capture with a lethal dose of tricaine methanesulfonate (MS-222) to prevent regurgitation of digestive tract contents. Other predators were retained alive in livewells with aerated and circulating water until processing of digestive tract contents could be completed.

Field data collected on northern squawfish included: fork length (FL, nearest mm), weight (nearest 5 or 10 g, depending upon fish size), sex, and stage of maturity. Scales were removed for age and growth information. Digestive tract contents from northern squawfish over 200 mm FL were taken by pinching off the anterior and posterior portions of the digestive tract, then removing the entire gut and placing it in a plastic bag. This technique was incorporated to facilitate the collection of coded-wire-tags (CWTs) from consumed fish.

Smallmouth bass, channel catfish, and walleye were anesthetized with MS-222, measured (FL), and weighed (nearest 5 to 10 grams). Scale samples (pectoral spine on channel catfish) were taken for age and growth information.

Stomach samples from smallmouth bass and walleye ≥150 mm FL were collected with a modified Seaburg stomach sampler (Seaburg 1957). Stomach contents from channel catfish were obtained by removing the entire digestive tract. All stomach and digestive tract contents were kept frozen until laboratory analysis.

Laboratory Methods

Northern Squawfish

In the laboratory, digestive tract samples were first checked for CWTs with a sensor. If a CWT was present the sample bag was marked for later tag removal. Samples were then thawed and removed from the sample bags. Gut contents were stripped from the entire digestive tract, examined with a magnifying lamp, and divided into major prey taxa groups (fish, crustacean, mollusks, etc.). Each prey group was blotted by placing the sample on tissue paper for 30 seconds. Prey groups were weighed to the nearest 0.01 g and returned to the sample bag. Blotting paper, sample bags, and petri dishes were examined with the CWT detector to ensure tags were still in the sample (occasionally tags were located in the blotting paper).

In order to speed lab processing of digestive tract contents, a digestive enzyme technique was used (Petersen et al. 1990). The enzyme solution was prepared using lukewarm tapwater, 2% w/w strength pancreatin (8x porcine digestive enzyme) and 1% w/w sodium sulfide. The solution was poured into sample bags until contents were submersed. Contents were briefly stirred to ensure all surface areas were in contact with digestive enzyme. Samples were placed in a desiccating oven at 45-50°C for 24 hr. After samples were removed from the oven, they were rechecked for CWTs. Tags were removed by shaking the bag and locating the tags along the bottom seam of the sample bag. Tags were put in a labeled vial for later identification. The rest of the sample bag contents were poured through a 425 micron (#40) sieve and rinsed with tap water. A dissecting scope and forceps were used to separate diagnostic bones (primarily cleithra, dentaries, and opercles) from other bones. Diagnostic bones were identified, paired to enumerate prey fish consumed, and preserved with 95% ethanol in labeled vials.

Smallmouth Bass

In the laboratory, smallmouth bass stomach samples were thawed, checked for CWTs, and processed in the manner described for northern squawfish. Prey fishes that were slightly digested were easily identified to species. Fishes in advanced stages of digestion were identified to family, genera, or species from diagnostic bones (Hansel et al. 1988) or vertebral columns (H. Hansel, U.S. Fish and Wildlife Service, unpublished data). The fork length of prey fishes was measured to the nearest mm. If a fork length could not be taken, the original fork lengths of prey fishes were estimated from measurements of standard length, nape to tail length (Vigg et al. 1991), or diagnostic bones (Hansel et al. 1988).

Consumption Index

A more detailed description and derivation for the northern squawfish CI were provided in Petersen et al. (1990, 1991); the CI equation and a brief description from Petersen et al. (1991) is presented here for completeness. The consumption index is:

$$CI = 0.0209 * T^{1.60} * MW^{0.27} * [MT,,, * MGutwgt^{-0.61}]$$

where T is water temperature, MW is mean predator weight (g), MT,,, is mean number of salmonids per predator, and MGutwgt is mean gut weight per predator (g). All variables in the CI are averaged over all predators in a sample; CI is the consumption index for a collection (sample) of predators. The CI for northern squawfish is not meant to be a rigorous method for estimating the number of juvenile salmonids eaten per day by an average predator. The CI is based on meal turnover time and does not consider certain aspects of consumption such as diel feeding patterns and evacuation rates of different prey items.

A bootstrap resampling technique was used to compute the distribution characteristics of northern squawfish CIs according to the methods outlined in Petersen et al. (1990, 1991). For each sample of N predators, a computer program randomly selected N individual predator records and calculated a new CI. Five hundred CIs were computed for each CI distribution and a mean and variance was calculated for each bootstrap sample. The number of predators per bootstrap sample was set to the original sample size (N), or 60 if N was greater than 60. Data for the CI and diet analyses were pooled in three different patterns based on rationale provided in Petersen et al. (1991; Figure 4). The use of the term "location" refers to a specific area of the reservoir sampled (e.g. forebay, tailrace, mid-reservoir). The term "reservoir-wide" refers to the area of a reservoir outside the BRZs, while "BRZ only" is the area in a forebay or tailrace location within the BRZ.

Smallmouth Bass Consumption Rate Estimates

To estimate smallmouth bass consumption rates of salmonids, we used a

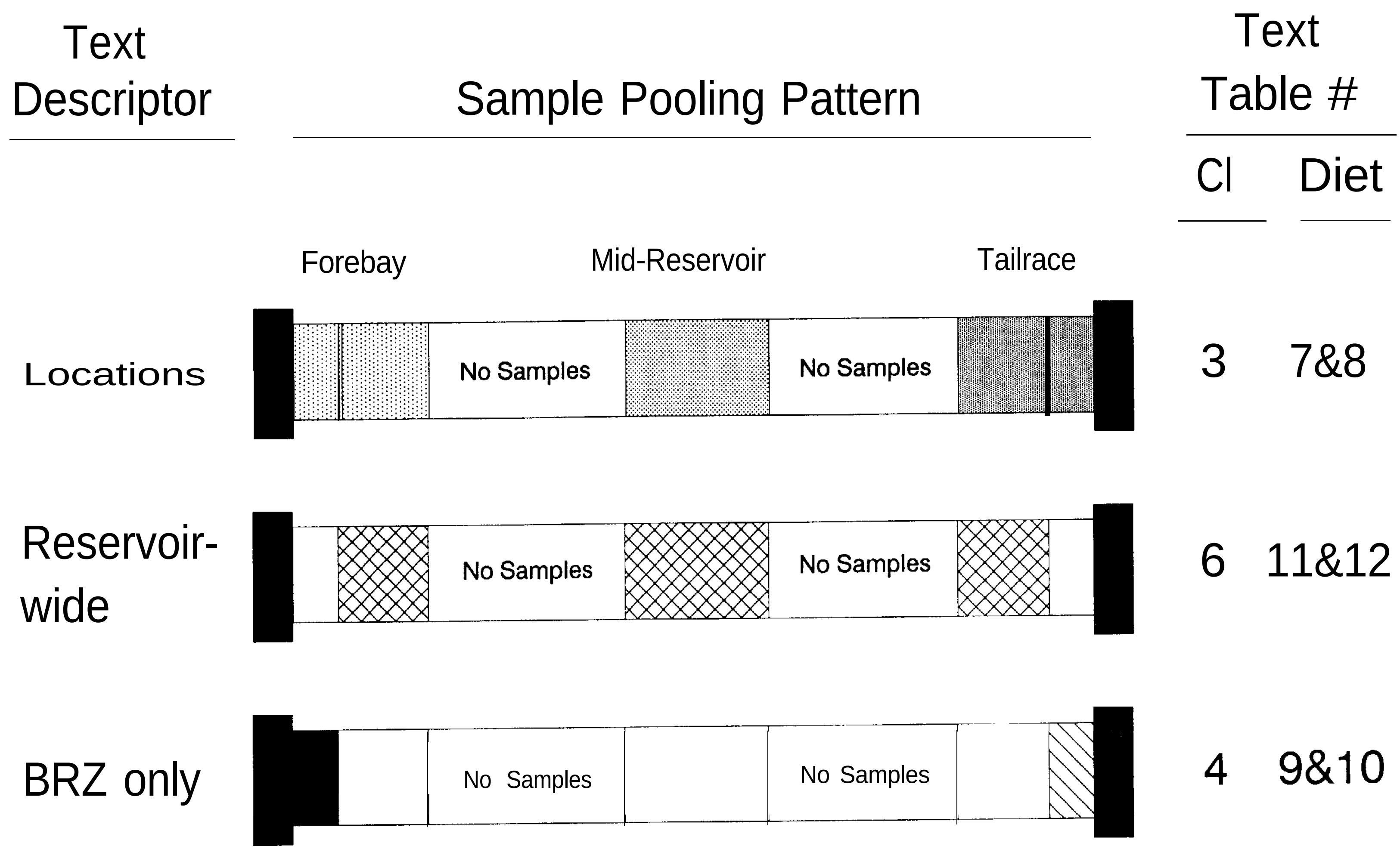

Figure 4. Sample pooling patterns for northern squawfish consumption index (Cl) and diet analyses. Each horizontal diagram represents a simple reservoir, bounded by two dams. For a particular analysis, data were pooled from areas of the reservoir having the same fill-pattern in the digram. Diagrams are not to scale.

simple meal turnover-time method adapted from Backiel (1971) and Henchman (1986). The original meal weight of fishes for each predator was estimated based on lengths of prey fishes. Weights of ingested prey fishes were estimated from length-weight regressions of forage fishes (Vigg et al. 1991). The original weights of non-fish prey items were estimated by adjusting the observed non-fish weight with the same ratio used for fish prey weight. This assumes fish and non-fish prey items were in similar states of digestion. Time to 90% digestion of the estimated meal weight was determined from digestion rate equations for smallmouth bass (Rogers and Burley 1991). To determine the number of salmonids consumed per day we first estimated consumption during our sampling period (≈ 0400-1100 h) and then adjusted the estimates based on diel feeding periodicity observed in John Day Reservoir (Vigg et al. 1991). Vigg et al. (1991) found that smallmouth bass consumed 32% of their daily ration between 0400 and 1100 h.

Bioenergetic Modeling

Work continued on the development and testing of a bioenergetics index to compliment the CI (Petersen et al. 1990, 1991). Specifically, we tried to estimate seasonal growth of northern squawfish during the juvenile salmonid out-migration period, which could be used to predict salmonid consumption. Two areas related to detection and measurement of seasonal growth were examined: 1) sample size requirements for estimating seasonal growth of northern squawfish; and 2) examination of alternative methods to scale ageing for estimating seasonal growth at specific locations.

Methods for collection and ageing of northern squawfish scales were described in Petersen et al. (1991). Samples collected during May and

September 1990 at the Bonneville mid-reservoir location (river km 273-285) were used for this study. Relatively large numbers of predators had been collected at these times, providing an adequate sample for scale selection. Northern squawfish were assigned to six cohort groupings based on ages determined during scale reading ($\leq$5,6,7,8,9,>9). Mean weights were calculated for each cohort for May and September and compared. To determine how mean weight changes during spring and summer we estimated seasonal growth by examining typical weight distributions of northern squawfish sampled during 1983-86 from McNary Dam boat restricted zone (BRZ) or within John Day Reservoir. Mean weight was calculated by month for northern squawfish $\geq$190 g (about 250mm FL). Data were examined primarily for within-year trends, rather than between-year patterns.

RESULTS

Catch

In 1991, a total of 3755 target predators were captured. Northern squawfish were the most abundant (56%, n=2118), followed by smallmouth bass (41%, n=1527), channel catfish (< 3%, n=100) and walleye (< 1%, n=10). All walleye were captured in John Day Reservoir (Table 2, Figure 5).

Of the 1821 northern squawfish captured in the Snake River, 45% were captured from the three tailrace locations. The largest number of northern squawfish were sampled at Lower Granite tailrace BRZ (22% of total catch). Thirty percent of the northern squawfish were captured in the upper reaches of the study area (Lower Granite Upper, Clearwater River, Asotin, and Rogersburg locations; n=643). The sex ratio for northern squawfish whose sex was determined was 43% males and 57% females. Ninety-seven percent of the northern squawfish had developing gonads. However, at Lower Monumental mid-reservoir 17% of the fish had gonads that were immature. Northern squawfish from the Snake and Clearwater rivers were significantly smaller (Pt0.001; $\bar{X}$ FL= 319 for males, x=376 mm for females) than fish captured from the John Day Reservoir ($\bar{X}$ FL= 353 mm for males, $\bar{X}$= 420 mm for females; Table 3).

Daily minimum and maximum sample sizes were based on data collected in John Day Reservoir (Petersen et al. 1990). We captured the minimum of 60 northern squawfish (15/day) at 8 of 15 Snake River locations, and in the BRZ of McNary tailrace. The maximum of 120 (30/day) northern squawfish was collected at 2 of 15 locations in the Snake River, and in the BRZ of McNary tailrace in the spring. In general, it was easier to capture target numbers

Table 2. Summary of major predators collected during the 1991 northern squawfish consumption indexing sampling. N=Number, M-Male, F=Female, U=Unidentified sex, SMB=Smallmouth bass, CHC=Channel catfish, WAL=Walleye. See Table 1 for description of locations.

RESERVOIR Location	NORTHERN SQUAWFISH N	M	F	U	SMB	CHC	WAL
Snake River							
ICE HARBOR							
1.Ice Harbor Fb	5	1	3	1	64	4	0
2.Ice Harbor Mr	17	6	8	3	161	2	0
3.Lower Monumental Tr	80	32	47	1	74	2	0
LOWER MONUMENTAL							
4.Lower Monumental Fb	31	5	26	0	51	1	0
5.Lower Monumental Mr	135	63	49	23	111	26	0
6.Little Goose Tr	275	137	129	9	105	42	0
LITTLE GOOSE							
7.Little Goose Fb	85	43	42		125	0	0
8.Little Goose Mr	16	10	6	8	179	17	0
9.Lower Granite Tr	468	203	261	4	65	0	0
LOWER GRANITE							
10.Lower Granite Fb	59	21	38		56	0	0
11.Lower Granite Mr	5	0	5	8	70	0	0
12.Lower Granite Up	133	46	82	5	75	0	0
13.Asotin	166	75	88	3	64	2	0
14.Clearwater R.	199	57	131	11	42	0	0
FREEFLOWING RIVER							
15.Rogersburg	147	55	87	5	87	0	0
Total	1821	754	1002	65	1329	96	0
Columbia River							
JOHN DAY							
Spring							
16.John Day Fb	24	4	20	0	50	0	0
17.John Day Mr	6	3	3	0	33	0	0
18.McNary Tr	148	45	100	3	4	3	10
Total	178	52	123	3	87	3	10
Summer							
16. John Day Fb	18	3	15	0	47	0	0
17.John Day Mr	3		2	0	43	0	0
18.McNary Tr	98	3:	66	0	16	1	0
Total	119	36	83	0	106	1	0

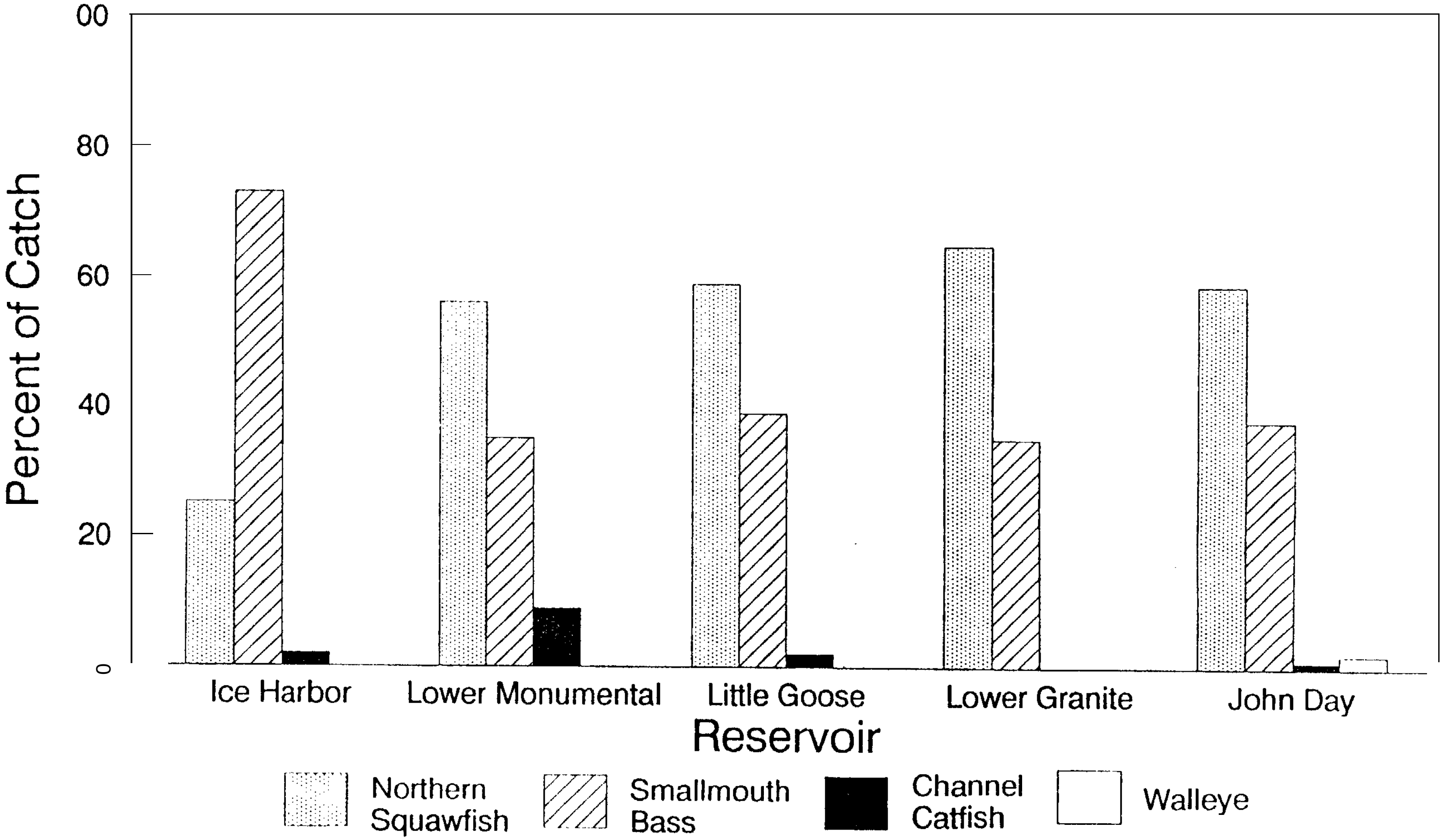

Figure 5. Percent of catch of predators per reservoir during the 1991 consumption indexing. Reservoirs are from dam to dam including BRZs. Lower Granite reservoir includes transects from the dam to the first set of rapids.

of northern squawfish within BRZs than non-BRZs. At locations away from the dams it was more difficult to sample adequate numbers of northern squawfish except at the four sites above Lower Granite mid-reservoir and during turbid conditions.

Smallmouth bass were more numerous than northern squawfish at all forebay and mid-reservoir locations except for Lower Granite forebay and Lower Monumental mid-reservoir where northern squawfish comprised about 50% of the total catch (Table 2). Thirty-nine percent of the smallmouth bass were collected from the four mid-reservoir locations (n=521) and 22% from the four forebay locations (n=298). Smallmouth bass accounted for 84 to 93% of the predators at the mid-reservoir locations of Ice Harbor, Little Goose, and Lower Granite. At forebay and tailrace locations the majority (69%) of smallmouth bass were captured in non-BRZ areas. Smallmouth bass captured in the free-flowing Rogersburg location were 14% larger (based on mean FL) than those captured elsewhere (Table 3).

A dramatic increase in turbidity caused by heavy rains in eastern Washington and Oregon was observed on 21 May at Little Goose mid-reservoir and at subsequent downstream locations. increased catches of most predators (northern squawfish, channel catfish, bullheads (I. spp), and crappie (Pomoxis spp.)were associated with the higher turbidity, most notably in mid-reservoir locations where catch numbers were low three weeks earlier.

Non-target predators, species which have shown evidence of piscivory, were also collected. These included bluegill (Lepomis macrochirus n=3), pumpkinseed (L. gibbosus n=2), yellow perch (Perca flavescens n=103), crappie (n=39), and bullhead (n=33). Nineteen fish that appeared to be northern squawfish x chiselmouth (Acrocheilus alutaceus) hybrids (Patten 1960) were also collected. Hybrids were sampled in all Snake River reservoirs except Ice Harbor. Incidental fish species commonly observed included: suckers (Catostomus spp.), carp (Cyprinus caroio), and chiselmouth. Less commonly observed were peamouth (Mvlocheilus caurinus), and mountain whitefish (Prosopium williamsoni). Rarely seen species included sandrollers (Percoosis transmontana), three-spine stickleback (Gasterosteus aculeatus), and prickly sculpin (Cottus asper).

Adult salmon, steelhead (Onchorvnchus mvkiss), and white sturgeon (Acipenser transmontanus) were occasionally shocked during sampling. The sampling crew stopped electrofishing to allow these fish to recover or drift out of the current field.

Diet of Northern Squawfish

In the laboratory, 1408 northern squawfish digestive tract samples from Snake River locations were analyzed. The overall diet of northern squawfish was dominated by fish and crustaceans (55.0% and 26.3%, respectively; Table 4). Fish were the most important prey item by weight for northern squawfish from most BRZ areas (Table 5) as well as many non-BRZ areas (Table 6). Crustaceans were often the dominant prey item of northern squawfish in reservoir-wide areas. Crayfish made up the greatest portion of crustacean weight. Amphipods (primarily Corpohium sp.) were also present, especially in small northern squawfish (<350 mm FL).

A total of 885 salmonids (mean 0.63 $salmonids \cdot fish^{-1}$) were consumed by northern squawfish (Table 7). Northern squawfish collected within BRZ areas contained significantly higher numbers of juvenile salmonids than reservoir-wide areas ($\bar{x}_{BRZ}$=0.83 $salmonids \cdot fish^{-1}$; $\bar{x}_{RES}$=0.53 $salmonids \cdot fish^{-1}$; P<0.001;

Table 4. Gut content of northern squawfish collected at locations in lower Snake River reservoirs and John Day Reservoir of the Columbia River during 1991. Gut contents (%) are the mean of percentages of individual northern squawfish. Crust.=crustacean; Moll.=mollusk; Tr=Tailrace; Fb=Forebay; Mr=Mid-reservoir; and Up=Upper reservoir.

RESERVOIR Location	N	Mean gut wt (g)	% empty guts	GUT CONTENTS (%)					
				Fish	Crust.	Mo??.	Insect	Plant	Other
SNAKE RIVER									
ICE HARBOR									
Ice Harbor Fb	8	0.05	75.0	0.0	100.0	0.0	0.0	...	0.0
Ice Harbor Mr	17	0.65	41.2	22.4	27.6	0.0	48.0	2.0	0.0
Lo. Monum. Tr	79	5.49	40.5	50.1	15.0	2.1	24.1	8.7	0.0
LOWER MONUMENTAL									
Lo. Monum. Fb	38	2.10	50.0	15.8	68.4	0.0	15.8	0.0	0.0
Lo. Monum. Mr	103	1.46	42.7	16.2	28.9	1.7		1.7	4.4
Lit. Goose Tr	188	8.96	35.1	59.9	36.4	0.3	47.6	0.2	1.6
LITTLE GOOSE									
Lit. Goose Fb	84	8.93	11.9	51.3	40.5	0.0		0.0	1.4
Lit. Goose Mr	15	4.94	6.7	13.4	56.2	0.0	6.9	22.5	0.0
L. Granite Tr	194	16.11	33.5	86.5	4.8	0.0	3.3	3.4	2:o
LOWER GRANITE									
L. Granite Fb	51	5.66	45.1	83.7	0.0	0.0		4.5	0.0
L. Granite Mr	5	1.17	80.0	0.0	100.0	0.0	10.8	0.0	0.0
L. Granite Up	128	6.92	41.4	29.9	45.3	1.4	9.2	9.7	4.6
Asotin	163	9.32	22.7	51.2	37.5	2.4	1.3	4.1	3.5
Clearwater R.	184	11.61	26.6	59.1	15.0	0.0	10.0	13.9	2.3
FREEFLOWING									
Rogersburg	145	9.65	22.8	56.5	21.1	1.7	5.0	11.7	4.0
COLUMBIA RIVER									
JOHN DAY									
A. Spring									
John Day Fb	23	15.51	21.7	88.9	5.6	0.0	5.6	0.0	0.0
John Day Mr	6	4.17	0.0	16.7	54.2	28.7	0.6	...	0.0
McNary Tr	79	14.15	29.1	82.7	11.6	2.0	3.6	0.0	0.2
B. Summer									
John Day Fb	17	4.45	41.2	50.0	10.0	0.0		0.0	0.2
John Mr	3	1.67	33.3	0.0	14.9	0.0	30.0	35.1	0.0
McNaryDay Tr	97	1.83	38.1	45.3	41.4	0.0	3.3	5:o	5.0

Table 5. Diet summary of northern squawfish collected within dam BRZs in the lower Snake River reservoirs and John Day Reservoir of the Columbia River during 1991. See Table 4 for explanation of columns.

RESERVOIR Location (in BRZ)		N	Mean gut wt (g)	% empty guts	GUT CONTENTS (%) Fish	Crust.	Mo??.	Insect	Plant	Other
SNAKE RIVER										
ICE HARBOR										
Ice Harbor	Fb	0	--	--	--	--			--	--
Lo. Monum.	Tr	55	4.53	36.4	50.1	9.8	2.9	29.5	7.8	0.0
LOWER MONUMENTAL										
Lo. Monum.	Fb	25	1.60	60.0	30.0	60.0	0.0	10.0	0.0	0.0
Lit. Goose	Tr	127	7.20	34.6	59.9	35.0	0.0	2.4	0.3	2.4
LITTLE GOOSE										
Lit. Goose	Fb	74	8.22	10.8	53.4	37.4	0.0	7.7	0.0	1.5
L. Granite	Tr	126	18.10	15.1	92.1	1.9	0.0	3.3	2.8	0.0
LOWER GRANITE										
L. Granite	Fb	51	5.66	13.7	83.7	0.0	0.0	11.8	4.5	0.0
COLUMBIA RIVER										
JOHN DAY										
A. Spring										
John Day	Fb	17	14.79	23.5	92.3	7.7	0.0	0.0	0.0	0.0
McNary	Tr	58	15.77	27.6	93.4	6.6	0.0	0.0	0.0	0.0
B. Summer							0.0	[illegible]		
John Day	Fb	12	6.23	33.3	50.0	0.0	0.0	[illegible]	0.0	0.2
McNary	Tr	78	2.02	20.5	50.3	42.0			3.8	3.8

Table 6. Diet summary of northern squawfish collected in reservoir-wide areas (excluding BRZ's) in lower Snake River reservoirs and John Day Reservoir of the Columbia River during 1991. See Table 4 for explanation of columns.

RESERVOIR (excluding BRZ's)	N	Mean gut wt (g)	% empty guts	GUT CONTENTS (%)					
				Fish	Crust.	Moll.	Insect	Plant	Other
SNAKE RIVER									
ICE HARBOR	42	1.15	54.8	27.6	33.7	0.0	30.5	8.3	0.0
								0.9	2.4
LOWER MONUMENTAL / LITTLE GOOSE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.2	4.8
LOWER GRANITE	488	2.24	30.1	35.6	57.9	0.0	4.3	1.3	0.8
FREEFLOWING	145	9.65	22.8	56.5	21.1	1.7	5.0	11.7	4.0
COLUMBIA RIVER									
JOHN DAY									
Spring	34	9.46	23.5	52.2	25.8	10.5	11.2	0.0	0.4
Summer	27	0.97	55.6	16.7	35.8	0.0	25.0	14.2	8.3

Table 7. Prey fish consumed by northern squawfish (SQF) collected at locations in lower Snake River reservoirs and John Day Reservoir of the Columbia River during 1991. FL=fork length; Mean Fish Wt.=mean prey fish mass (g) per predator; % smolts= percent of the total number of fish consumed that were smolts. Tr=Tailrace; Fb=Forebay; Mr=Mid-reservoir; Up=Upper reservoir.

PREDATORS			PREY FISH CONSUMED					
RESERVOIR Location	N	Mean FL (mm)	Mean Fish wt. (g)	Total # Smolts	# Smolts Per SQF	% Smolts	Total # Other Fish	% Other Fish
SNAKE RIVER								
ICE HARBOR								
Ice Harbor Fb	8	326	0.00	0	0.000	--	0	---
Ice Harbor Mr	17	296	0.10	0	0.000	0.0	3	100.0
Lo. Monum. Tr	79	361	4.76	30	0.380	60.0	20	40.0
LOWER MONUMENTAL								
Lo. Monum. Fb	38	344	0.93	3	0.079	100.0	0	0.0
Lo. Monum. Mr	103	280	0.37	0	0.000	0.0	21	100.0
Lit. Goose Tr	188	319	7.41	94	0.500	77.0	28	23.0
LITTLE GOOSE								
Lit. Goose Fb	84	341	6.71	58	0.690	98.3	1	1.7
Lit. Goose Mr	15	319	0.59	0	0.000	0.0	2	100.0
L. Granite Tr	194	371	15.76	254	1.309	94.4	15	5.6
LOWER GRANITE								
L. Granite Fb	59	353	5.08	46	0.780	93.9	3	
L. Granite Mr	5	437	0.00	0	0.000	-	0	6.1 -
L. Granite Up	128	374	2.48		0.250	91.4	3	8.6
Asotin	163	369	6.20	1::	0.681	71.6	44	28.4
Clearwater R.	184	370	9.10	157	0.853	84.9	28	15.1
FREEFLOWING								
Rogersburg	145	370	7.50	101	0.697	87.1	15	12.9
COLUMBIA RIVER								
JOHN DAY								
A. Spring							7	[illegible]
John Day Fb	23	414	15.48	29	1.261	80.6	0	10.0
John Day Mr	6	366	1.19	1	0.167	100.0		[illegible]
McNary Tr	79	401	13.48	83	1.051	90.2	9	9.8
B. Summer								
John Day Fb	17	399	2.68	9	0.529	100.0	0	0.0
John Day Mr	3	398	0.00	0	0.000	---	0	
McNary Tr	97	389	1.28	28	0.289	53.8	24	46.2 ---

Table 8. Prey fish consumed by northern squawfish (SQF) collected within dam BRZ's in lower Snake River reservoirs and John Day Reservoir of the Columbia River during 1991. See Table 5 for explanation of columns.

PREDATORS			PREY FISH CONSUMED					
RESERVOIR Location (in BRZ)	N	Mean FL (mm)	Mean Fish wt. (g)	Total # Smolts	# Smolts Per SQF	% Smolts	Total # Other Fish	% Other Fish
SNAKE RIVER								
ICE HARBOR								
Ice Harbor Fb	0	---	---	--	---		--	---
Lo. Monum. Tr	62	359	5.77	27	0.435	5714	20	42.6
LOWER MONUMENTAL								
Lo. Monum. Fb	25	361	1.41	3	0.120	100.0	0	0.0
Lit. Goose Tr	127	317	5.65	59	0.465	77.6	17	22.4
LITTLE GOOSE								
Lit. Goose Fb	74	337	6.10	51	0.689	98.1	1	2.0
L. Granite Tr	126	373	17.82	203	1.611	94.9	11	5.1
LOWER GRANITE								
L. Granite Fb	51	343	5.53	43	0.843	93.5	3	6.5
COLUMBIA RIVER								
JOHN DAY								
A. Spring								
John Day Fb	17	418	14.76	23	1.353	85.2	4	14.8
McNary Tr	58	396	15.68	73	1.259	100.0	0	0.0
B. Summer								
John Day Fb	12	393	3.72	8	0.667	100.0	0	0.0
McNary Tr	78	396	1.56	28	0.359	54.9	23	45.1

Table 9. Prey fish consumed by northern squawfish (SQF) collected in reservoir-wide areas in lower Snake River resrvoirs and John Day Reservoir of the Columbia River during 1991. See Table 5 for explanation of columns.

PREDATORS			PREY FISH CONSUMED					
RESERVOIR (excluding BRZ's)	N	Mean FL (mm)	Mean Fish wt. (g)	Total # Smolts	# Smolts Per SQF	% Smolts	Total # Other Fish	% Other Fish
SNAKE RIVER								
ICE HARBOR	42	330	0.48	3	0.071	50.0		50.0
LOWER MONUMENTAL	177	297	4.08	35	0.198	52.2	3:	47.8
LITTLE GOOSE	93	361	10.06	58	0.624	89.2	7	10.8
LOWER GRANITE	488	372	6.20	303	0.621	84.6	55	15.4
ROGERSBURG (Free-Flowing)	145	370	7.50	101	0.697	87.1	15	12.9
COLUMBIA RIVER								
JOHN DAY								
Spring	36	394	7.63	20	0.556	62.5	12	37.5
Summer	27	376	0.13	1	0.037	50.0	1	50.0

Tables 8 and 9) northern squawfish collected at mid-reservoir sites did not contain any salmonids. In contrast, northern squawfish collected at Lower Granite upper reservoir, Asotin, Clearwater, and Rogersburg locations consumed high numbers of salmonids (Table 7).

Other species of preyfish comprised only 17% of the total number of fish ingested by northern squawfish. Sculpins were the predominant non-salmonid fish ingested by northern squawfish in the free-flowing areas. In reservoir-wide areas, fish consumed by northern squawfish were predominantly ictalurids and centrarchids.

We examined the guts of 225 northern squawfish from John Day Reservoir. The overall diet of northern squawfish was dominated by fish and crustaceans (62.8% and 24.3% respectively, Table 4). Generally, within the BRZs fish were the primary prey item, with salmonids comprising 83% of the total prey fish (Table 8). During the summer sampling period crustaceans and insects became more important. Reservoir-wide, the trend was similar except that during the summer sampling period crustaceans and insects were the major components of the diet with fish having a secondary role (Table 6). The greatest number of salmonids per northern squawfish were from fish collected within the BRZs during the spring, with John Day forebay being the highest (1.4 salmonids$\cdot$fish^{-1}; Table 8). Generally, summer samples had a higher percentage of empty digestive tracts than spring samples.

Diet of Smallmouth Bass

We analyzed stomach contents of 1145 smallmouth bass collected from Snake River locations. Crustaceans (primarily crayfish) dominated the diets of smallmouth bass (64%), followed by fish (27%; Table 10), with the exception

Table 10. Diet summary of smallmouth bass in reservoir-wide areas (including BRZs) in the lower Snake River and John Day Reservoir of the Columbia River during 1990. See Table 4 for explanation of columns.

RESERVOIR Fork length (mm)	N	Mean gut wt (9)	% empty guts	DIGESTIVE TRACT CONTENTS (%) Fish	Crust.	Moll.	Insect	Plant	Other
SNAKE RIVER									
ICE HARBOR									
150-199	70	0.17	47.1	16.1	72.1	1.6	2.7	0.0	7.6
200-249	112	0.85	43.8	23.8	57.1	0.0	11.1	0.0	8.2
250-299	50	1.03	38.0	28.3	53.1	0.0	3.1	4.0	11.6
> 300	31	0.96	32.3	51.2	35.1	0.0	8.4	0.0	5.3
Total	263	0.72	42.2	26.6	56.9	0.4	7.1	0.8	8.3
LOWER MONUMENTAL									
150-199	29	0.32	51.7	4.4	86.0	0.0	2.4	0.0	7.1
200-249	93	0.82	33.3	17.3	80.4	0.0	1.9	0.0	0.4
250-299	71	1.02	28.2	23.2	71.1	0.0	3.0	2.0	0.8
> 300	28	3.92	35.7	43.8	44.7	0.0	6:0	5.6	0.0
Total	221	1.21	34.4	21.4	73.3	0.0	2.8	1.4	1.1
LITTLE GOOSE									
150-199	79	0.41	29.1	10.8	88.3	0.0	0.9	0.0	0.1
200-249	130	1.14	15.4	16.6	78.6	0.1	3.4	0.1	1.3
250-299	79	2.60	12.7	16.4	80.1	0.0	3:0	0.0	0.5
> 300	26	7.03	7.7	17.5	74.0	0.0	4.2	0.2	4.2
Total	314	1.81	17.5	15.4	80.7	0.0	2.8	0.0	1.1
LOWER GRANITE									
150-199	55	0.29	60.0	9.1	77.3	0.0	13.6		0.0
200-249	73	0.60	45.2	15.7	78.2	0.0	6.1	8.[illegible]	0.0
250-299	78	2.39	21.8	39.4	56.3	0.0	2.1	1.7	0.5
> 300	49	6.41	14.3	59.5	35.3	0.0	0.3	2.5	2.4
Total	255	2.18	34.8	34.7	59.1	0.0	4.2	1.3	0.8
ROGERSBURG									
150-199	1	0.00	100.0						
200-249	3	0.31	33.3	32.0	0.0	0.0	18.0	50.0	0.0
250-299	39	0.91	33.3	65.4	19.4	0.0	7.5	4.5	3.2
> 300	37	2.46	29.7	70.3	15.7	0.0	2.1	8.8	3.1
Total	80	1.59	32.5	66.5	16.9	0.0	5.3	8.2	3.0

Table 10 continued.

RESERVOIR Fork length (mm)	N	Mean gut wt (g)	% empty guts	DIGESTIVE TRACT CONTENTS (%) Fish	Crust.	Moll.	Insect	Plant	Other
COLUMBIA RIVER									
JOHN DAY									
A. Spring									
150-199	14	0.11	57.1				0.0		0.0
200-249	36	1.01	16.7	32.7	67.3	0.0	4.7	0.0	0.0
250-299	19	1.38	36.8	30.7	64.6	0.0	0.1	0.1	5.0
> 300	9	4.15	0.0	[illegible]	[illegible]	0.0	0.0	0.0	0.0
Total	80	1.46	27.5	34.2	62.3	0.0	2.4	0.0	1.0
B. Summer									
150-199	12	0.60	8.3		77.0		9.2		5 5
200-249	37	2.12	21.6	6.3		0.0		2.1	[illegible]
250-299	26	2.49	11.5	23.0	64.3 56.5	0.0	12.1 7.3	0.0	0.0
> 300	21	6.82	19.0	65.1	21.6	0.0	1.5	11.8	0.0
Total	96	3.06	16.7	33.4	54.7	0.0	8.1	2.8	1.0

of the Rogersburg location where fish was the major diet component. The percent of fish in the diet increased with smallmouth bass size, and consumption of juvenile salmonids was seen primarily in large smallmouth bass (of the smallmouth bass that ingested salmonids, 90% were greater than 280mm FL; Table 11). However, overall consumption rates of salmonids by smallmouth bass were low ($\bar{x}$= 0.01 salmonids·fish^{-1}·day^{-1}).

Stomach contents from other predators have not been processed and those data will be included in next years' annual report.

Northern Squawfish Consumption Index

Consumption index values at Snake River sites ranged from zero at all mid-reservoir locations to 1.2 at Lower Granite Forebay (Table 12). In John Day Reservoir spring CI values ranged from 0.5 at John Day mid-reservoir to 1.9 at John Day Forebay, and 0.9 to 3.0 at the same locations during the summer sampling period (Table 12). Mean CI values generated from bootstrap analyses were similar to actual CI values as expected. Coefficients of variation (CV) of the mean CIs were inversely related to sample size and ranged from 11%-65% ($\bar{x}$=23%) at Snake River locations and 12%-90% at John Day Reservoir locations (Table 12).

In the Snake River, CI values for northern squawfish collected were highest in forebay and tailrace areas (Table 12), and were slightly higher for fish collected in restricted than in non-restricted zones (Tables 13 and 14). All mid-reservoir locations had CI values for northern squawfish of 0 (i.e. no salmonids were found in digestive tracts examined). Also, CI values for northern squawfish were moderate (0.3-0.8) at the four locations above Lower Granite mid-reservoir where high numbers of northern squawfish were captured.

Table 11. **Prey fish consumed by smallmouth bass (SMB) in reservoir-wide areas (including BRZs) in the lower Snake River and John Day Reservoir of the Columbia River during** 1990. **See Table 5 for explanation of columns.**

			PREY FISH CONSUMED					
RESERVOIR Fork Length (mm)	N	Mean Fish wt. (g)	Total # Smolts	# Smolts per SMB	# Smolts per day	% Smolts	Total # Other Fish	% Other Fish
SNAKE RIVER								
ICE HARBOR								
150-199	70	0.143	0	0.000		0.0	6	100.0
200-249	112	0.173	0	0.000	8	0.0	19	100.0
250-299	50	0.324	0	0.000	0	0.0	11	100.0
> 300	31	9.048	1	0.032	0.012	5.9	16	94.1
Total	263	1.239	1	0.004	0.001	1.9	52	98.1
LOWER MONUMENTAL								
150-199	29	0.004	0	0.000	0	0.0	1	100.0
200-249	93	0.151	0	0.000	0	0.0	20	100.0
	71	0.195	0	0.000	0	0.0	20	100.0
≥5300299	28	3.065	6	0.214	0.050	35.3	11	64.7
Total	221	0.515	6	0.027	0.007	10.3	52	89.7
LITTLE GOOSE								
150-199	79	0.045	0	0.000	0	0.0	8	100.0
200-249	130	0.311	0	0.000	0	0.0	34	100.0
	79	0.512	4	0.051	0.016	15.4	22	84.6
≥5300299	26	2.840	3	0.115	0.032	25:0	9	75.0
Total	314	0.504	7	0.022	0.007	8.8	73	91.3
LOWER GRANITE								
150-199	51	0.026	0	0.000	0	0.0	2	100.0
	70	0.105	0	0.000	0	0.0	32	100.0
260-2499	75	1.445	8	0.107	0.033	27.6	21	72.4
> 300	48	6.542	23	0.479	0.135	69.7	10	30.3
Total	244	1.766	31	0.127	0.037	32.3	65	67.7
ROGERSVILLE								
150-199	1	0.008	0	0.000	0	0.0	2	100.0
	3	0.323	0	0.000	0	0.0	11	100.0
260-2949	39	0.575	1	0.026	0.008	1.6	62	98.4
> 300	37	2.529	6	0.162	0.041	12.2	43	87.8
Total	80	1.462	7	0.088	0.023	5.6	118	94.4

Table 11. continued.

RESERVOIR Fork Length (mm)	N	Mean Fish wt. (g)	Total # Smolts	# Smolts per SMB	# Smolts per day	% Smolts	Total # Other Fish	% Other Fish
		PREY FISH CONSUMED						
COLUMBIA RIVER								
JOHN DAY								
A. Spring								
150-199	14	0.024	8	0.000	0	0.0	1	100.0
200-249	36	0.661		0.000	8	0.0	11	100.0
250-299	19	0.563	0	0.000		[illegible]	4	100.0
> 300	9	3.433	8	0.000	0	0.0	5	100.0
Total	80	1.011		0.000	0	0.0	22	100.0
B. Summer								
150-199	12	0.067	0	0.000	0	0.0	1	100.0
200-249	37	0.877	3	0.115	22;	21.4	10	100.0
250-299	26	1.091		[illegible]	[illegible]	[illegible]	14	78.6
> 300	21	6.137	8	0.381	0.200	36.4	36	63.6
Total	96	1.984	11	0.115	0.106	23.4		76.6

Table 12. Northern Squawfish consumption indices (CI) at locations in the Snake, Clearwater, and Columbia rivers during 1991. Note that a single 0 means no juvenile salmonids were found in the predator digestive tracts. CI is the consumption index for the original sample (N). Mean CI, standard deviation (SD), coefficient of variation, (CV, %) and quartiles are given for the 500 bootstrap samples. Tr=Tailrace, Fb=Forebay, Mr=Mid-reservoir, Up=Upper.

RESERVOIR Location		N	CI	Bootstrap Summary				
							Quartiles	
				Mean	SD	CV%	25th	75th
Snake River								
ICE HARBOR								
Ice Harbor	Fb	5	0		00	--	0	0
Ice Harbor	Mr	16	0	0	0	--	0	0
Lower Monumental	Tr	80	0.8	0.8	0.2	19	0.7	0.9
LOWER MONUMENTAL		31						
Lower Monumental	Fb	104	0.2	0.2	0.2	65	0.1	0.3
Lower Monumental	Mr			0	0	--	0	0
Little Goose	Tr	186	0.9	0.7	0.1	21	0.6	0.8
LITTLE GOOSE								
Little Goose	Fb	84	1.0	0.9	0.1	14	0.9	1.0
Little Goose	Mr	16	0	0	0	--		0
Lower Granite	Tr	191	1.0	1.0	0.1	12	1.8	1.1
LOWER GRANITE								
Lower Granite	Fb	59	1.2	1.2	0.1	11	1.1	1.3
Lower Granite	Mr	5	0	0	0		0	0
Lower Granite	Up	127	0.3	0.3	0.1	28	0.3	0.4
Asotin		164	0.8	0.8	0.1	16	0.7	0.9
Clearwater River		183	0.6	0.6	0.1	17	0.5	0.7
FREEFLOWING RIVER								
Rogersburg		146	0.8	0.8	0.1	14	0.7	0.8
Columbia River								
JOHN DAY								
A. SPRING								
McNary	Tr	82	1.4	1.4	0.2	12	1.3	1.6
John Day	Mr	6	0.5	0.5	0.4	90	0	0.9
John Day	Fb	23	1.9	2.0	0.3	15	1.8	2.2
B. SUMMER								
McNary	Tr	96	2.4	2.3	0.6	28	1.8	2.7
John Day	Mr	6	0.9	0.8	0.6	82		1.3
John Day	Fb	18	3.0	3.0	0.9	32	2.30	3.6

Table 13. Consumption indices (CI) of northern squawfish within dam BRZs in the Snake, Clearwater, and Columbia Rivers during 1991. See Table 12 for explanation of columns.

RESERVOIR Location (BRZ only)		N	CI	Bootstrap Summary Mean	SD	CV%	Quartiles 25th	75th
Snake River								
ICE HARBOR								
Ice Harbor	Fb	0	---	---	---	--	---	---
Lower Monumental	Tr	63	0.8	0.8	0.2	20	0.7	0.9
LOWER MONUMENTAL								
Lower Monumental	Fb	19	0.5	0.3	0.2	60	0.1	0.4
Little Goose	Tr	126	0.7	0.7	0.1	16	0.6	0.8
LITTLE GOOSE								
Little Goose	Fb	74	1.0	1.0	0.1	12	0.9	1.1
Lower Granite	Tr	123	1.2	1.2	0.1	10	1.1	1.3
LOWER GRANITE								
Lower Granite	Fb	51	1.2	1.2	0.1	11	1.1	1.3
Columbia River								
JOHN DAY								
A. SPRING								
McNary	Tr	55	1.5	1.5	0.2	10	1.4	1.6
John Day	Fb	17	2.2	2.2	0.4	17	2.0	2.4
B. SUMMER								
McNary	Tr	76	2.8	2.8	0.7	24	2.3	3.2
John Day	Fb	12	3.2	3.2	1.1	34	2.4	3.9

Table 14. Reservoir-wide (excluding BRZs at dams) CIs of northern squawfish during the 1991 sampling in the lower Snake and Columbia Rivers. See Table 12 for explanation of columns.

RESERVOIR (excluding BRZs)	N	CI	Bootstrap Summary				
						Quartiles	
			Mean	SD	CV	25th	75th
Snake River							
ICE HARBOR	38	0.4	0.4	0.2	42	0.3	0.5
		0.6	0.4	0.1			0.4
LOWER MONUMENTAL / LITTLE GOOSE	97 / 146	0.6	0.6	0.1	28 / 14	0.3 / 0.6	0.7
LOWER GRANITE	488		0.6	0.1	16	0.5	0.7
Columbia River							
SPRING							
JOHN DAY	36	0.9	1.0	0.3	36	0.8	1.1
SUMMER							
JOHN DAY	31	0.7	0.6	0.4	67	0.3	0.9

Reservoir-wide (i.e. areas not including BRZs) CIs for northern squawfish ranged from 0.6 at Lower Granite and Little Goose reservoirs to 0.3 at Lower Monumental (Table 14).

Bioenergetic Modeling

Mean weight of northern squawfish increased significantly between May and September only for the two age groups <5 and 6 yrs; these groups also had the largest sample sizes (Table 15). Fish <5 and 6 yrs old showed the largest percentage weight change during the growth season (36% and 24%, respectively). Fish 7 yrs old increased 69 g, but this change was not significantly different from zero. Mean weight of older (8, >9 yrs) fish declined, although these weight losses were not significantly different from zero and sample sizes were relatively small. The coefficients of variation (CV) were slightly higher during the spring than during the fall. Coefficients of variation declined with increasing age of fish during the fall, suggesting less weight variability in the older age groups.

Changes in mean fish weights suggest that only younger individuals showed significant positive growth during the summer in Bonneville mid-reservoir; older fish did not gain weight during the spring and summer. Such a conclusion is possible, meaning older fish were simply feeding at a maintenance level during this period. Non-growing fish might still be consuming a significant number of smolts.

Age and growth results from 1990 were used to estimate the minimum sample sizes of aged northern squawfish needed in future bioenergetic studies to determine if the age and growth procedure was feasible at several locations, or if sampling requirements would be too great. Because of the

Table 15. Mean weignt (g) and Coefficient of Variation (CV as %) of northern squawfish col lected at Bonneville mid-reservoir during Spring (May) and Fall (September) 1990. Change in weight between spring and fall is shown as the "Difference" (g). The probability that the difference was 0 is shown beneath P (t-tests).

		Spring			Fall			
Age	**N**	**Mean Weight**	**CV**	**N**	**Mean Weight**	**CV**	**Difference**	**P**
25	8	290	17	8	395	24	105	.01
6	17	395	28	14	489	23	94	.03
7	4		41	5		17	69	
8	4	585 778	31	6	654 671	13	-107	.34
9	6	1015	25	5	1014	8	- 1	.99
>9	5	1146	33	3	980	8	-166	.50
			29					
≤ 6	25	362	36	22	455	25		
7-8	8	681		11	664	14		
≥ 9	11	1075	29	8	1001	7		

relatively small numbers of northern squawfish aged, we lumped fish into three age-groups: ≤ 6, 7-8, and ≥ 9 years of age (Table 15). Mean and standard deviation of each age-group in the spring were used to estimate sample sizes needed to detect weight change of 10% to 40% (Figure 6). The percentage weight changes that were tested spanned the observed seasonal growth of 5-9 year-old northern squawfish in Bonneville Reservoir (Table 15), and such growth might be expected elsewhere.

Detecting a relatively small change in growth (+10%) would require quite large numbers (>80) of northern squawfish to be caught and aged in each age-group (Figure 6). Larger percentages of growth (>20%) would require considerably fewer aged individuals (<20). The seasonal changes in weight we observed for northern squawfish in the Bonneville mid-reservoir location were less than 20% for all older cohorts (Table 15), although smaller fish generally added more than 20% of their body weight during the spring to fall period (Table 15). These conclusions about sample size are similar to those of Petersen et al. (1990).

Using 1983-86 data from John Day Reservoir, mean predator weight remained constant or declined slightly in McNary tailrace BRZ between April and June; only in 1984 did mean weight increase slightly during this period (Figure 7). In 1985 and 1986, mean weight declined considerably from June to July, probably because of spawning losses (U.S. Fish and Wildlife Service, unpublished data). Mean predator weight showed a small increase from July to August where data were available (1985, 1986).

In the John Day pool, mean predator weight was significantly less than the weight of predators captured in McNary tailrace BRZ (Figure 7), but within-year trends were similar. For all years, the mean predator weight

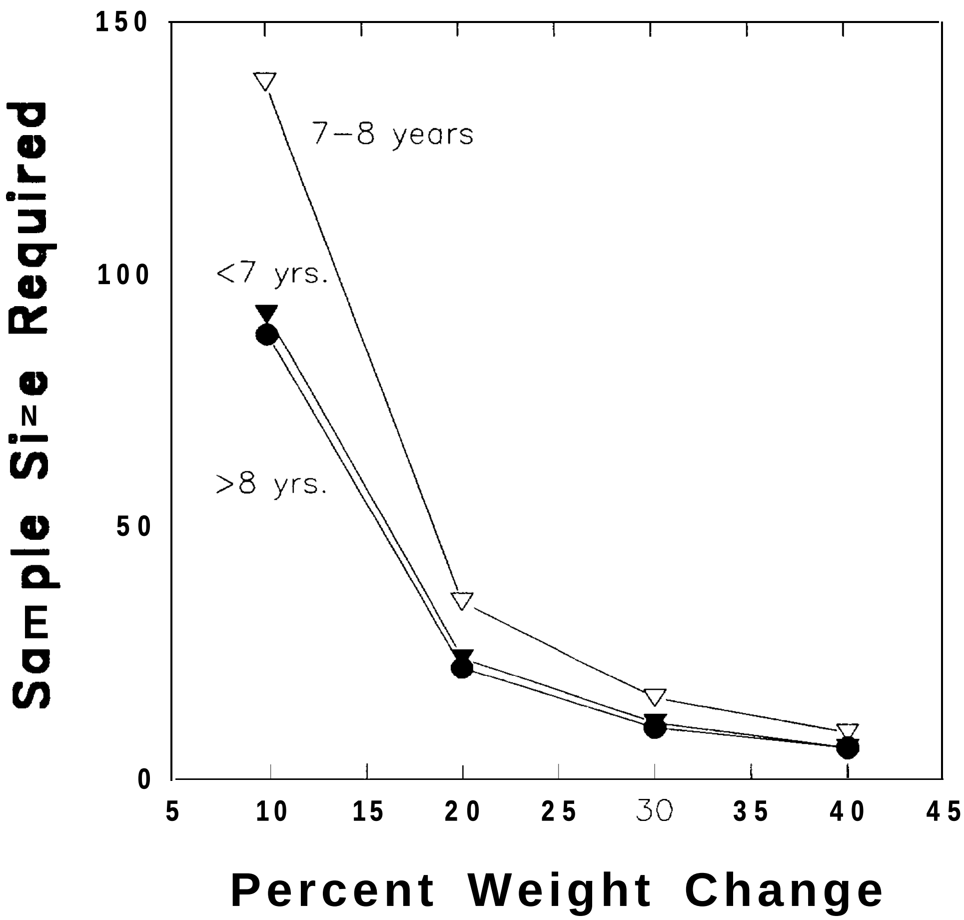

Figure 6. Number of aged northern squawfish required to detect a percentage weight change.

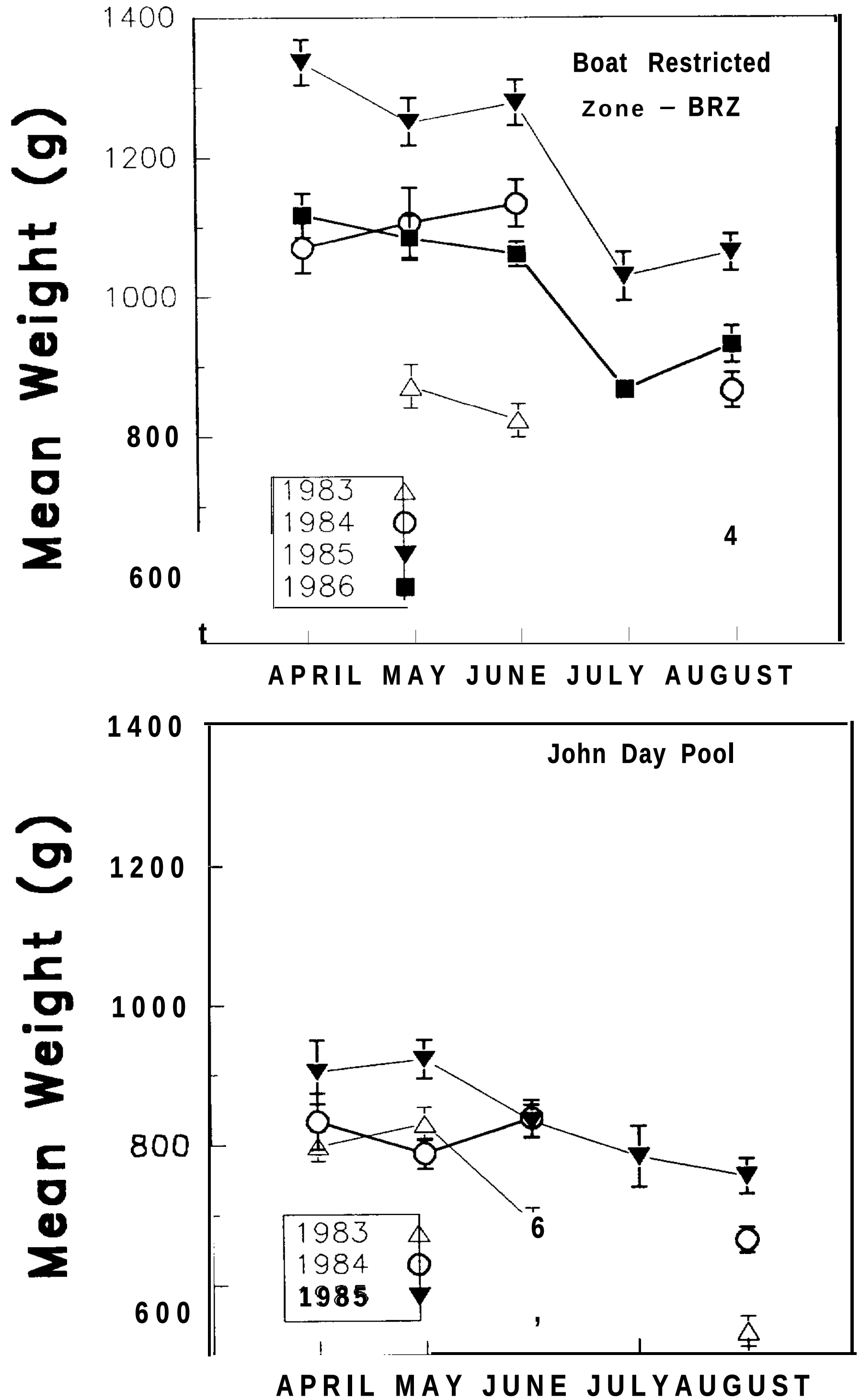

Figure 7. Mean monthly weight of northern squawfish from McNary Dam BRZ and John Day pool (1983-1986).

gradually declined during April to August in the pool. Northern squawfish did not show any increase in weight during the late summer as was observed in the BRZ, although only one year's data (1985) were available from the reservoir for this period.

DISCUSSION

According to Petersen et al. (1991), the goal of predation indexing is "to provide a ranking of locations and reservoirs throughout the Columbia River basin according to the intensity of predation upon juvenile salmonids." As part of the study design, John Day Reservoir was to be sampled every year to provide data on inter-annual trends. Due to the low water temperatures encountered while sampling Snake River locations (range 6-13°C) any comparisons to Columbia River locations should be made with data from the spring sampling period (1990 water temperature range 10-13°C; 1991 11.5-13°C).

Northern squawfish CIs for Snake River locations were highest around hydroelectric projects and lowest at mid-reservoir locations. The same trend was observed in 1990 for lower Columbia River reservoirs (Petersen et al 1991; Appendix A). However, the relative magnitude of predation at Snake River locations was lower ($\bar{x}$ CI=0.5, range 0-1.2) than at lower Columbia River locations in the spring (1990 $\bar{x}$ CI=1.3, range 0-4.8; 1991 $\bar{x}$ CI=1.3, 0.5-1.9) even though the mean number of salmonids per northern squawfish were not significantly different between years (1990 0.71 salmonids$\cdot$fish^{-1}; 1991 0.63 salmonids$\cdot$fish^{-1}; P=0.35). We offer several possible explanations for the lower CIs. First, water temperatures were lower at Snake River locations than Columbia River locations in spring, which would result in slower evacuation rates by northern squawfish (Beyer et al. 1988). Second, large numbers of salmonids are bypassed and transported from Lower Granite and Little Goose dams; thus fewer salmonids may have been available to northern squawfish. Also, the mean size of northern squawfish captured at Snake River locations was about 10% smaller than fish captured in John Day Reservoir. Vigg et al. (1991) reported that larger northern squawfish had the highest consumption rates on juvenile salmonids; therefore, the smaller size of fish captured may contribute to the lower CIs observed. Although CI values were zero (i.e. no salmonids were found in northern squawfish digestive tracts) for all Snake River mid-reservoir sites, it is unlikely that northern squawfish do not consume any juvenile salmonids in these locations based on data from John Day Reservoir (Poe et al. 1991).

Although we did not collect the predetermined daily minimum sample sizes of northern squawfish at 7 of 15 locations, we believe in most areas our CI results are still valid for two reasons. The predetermined daily sample sizes were based on data from John Day Reservoir (Petersen et al. 1990). However, coefficients of variation of the mean CIs at Snake River locations were lower ($\bar{x}$ CV=23%) than at Columbia River locations in 1990 ($\bar{x}$ CV=43%) indicating the the amount of salmonids in the diet of northern squawfish was less variable at Snake River locations. We also performed pair-wise tests of hypothetical comparisons of CI values (CI vs. CI/2, and CI vs. CI*2) from locations where we did not achieve our minimum sample size and determined the statistical power ($1-\beta$; probability of a type II error, $\alpha=0.05$) of the tests. Average power was >99% at all locations except at John Day mid-reservoir where average power was 42% for CI vs. CI/2 and 88% for CI vs. CI*2.

We tried to coordinate sampling at Snake River locations with hatchery releases and historic passage of juvenile salmonids at dam locations, particularly spring chinook salmon (Onchorvnchus tschawvtscha) because of their susceptibility to predation by northern squawfish (Poe et al. 1991). In general, timing of sampling coincided with increased numbers of salmonids at most locations except at Lower Monumental Dam where CI values were low (Figure 8). Of interesting note, we sampled at the Clearwater River 12 h after a

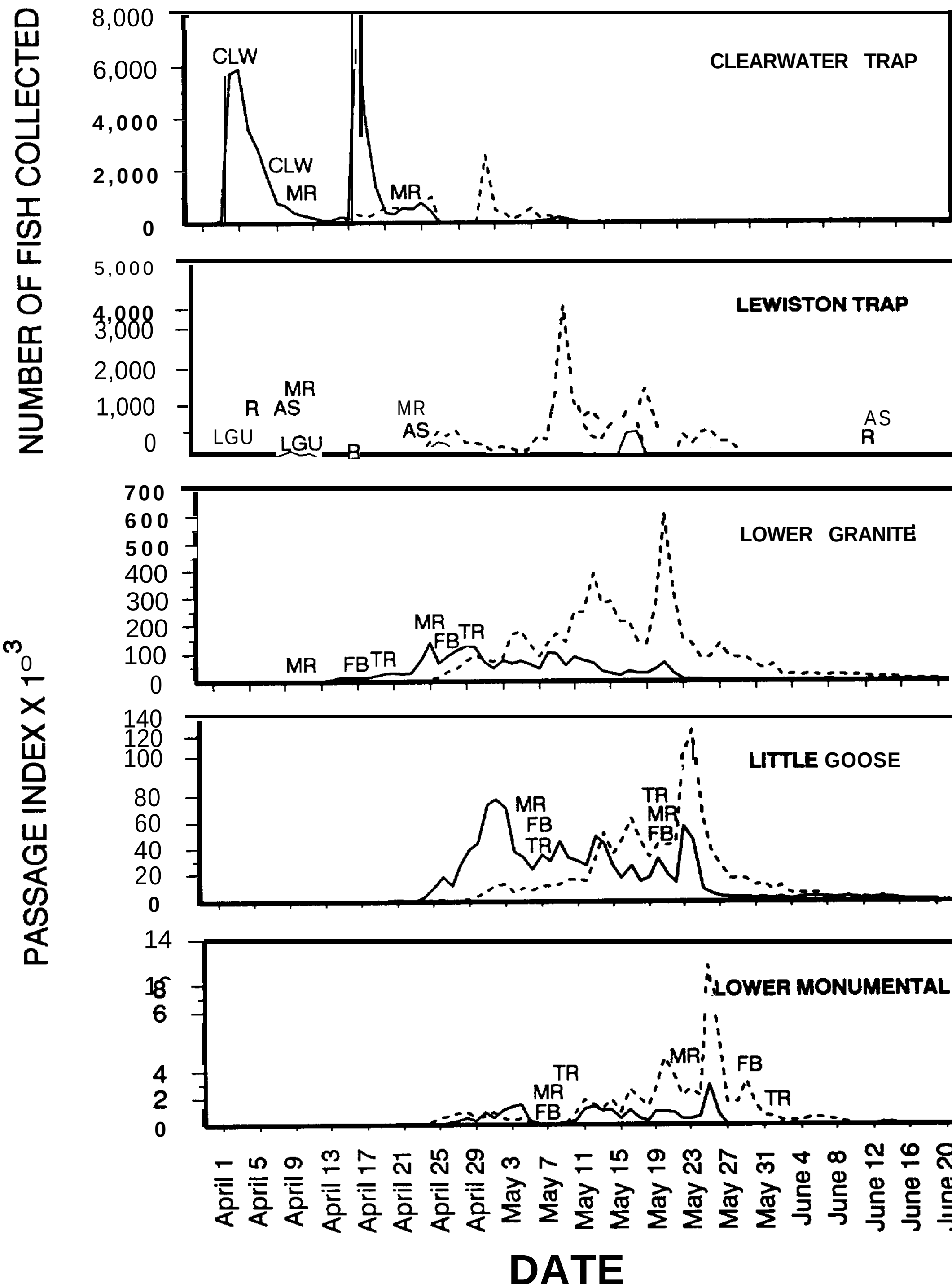

Figure 8. Timing of consumption index sampling at Snake River locations with respect to spring chinook (solid line) and steelhead (dotted line) passage indices at mainstem dams and trap facilities. Approximate sample times for tailrace (TR), forebay (FB), Upper-reservoir (UP), immediate downstream mid-reservoir (MR), and other locations are shown in a panel. The MR location in the Lower Granite panel, for example, actually represents sampling at Little Goose mid-reservoir location. Passage data from the Fish Passage Center, 1991.

release of about 1 million spring chinook salmon from Dworshak National Fish Hatchery and despite the low water temperatures (6°C) northern squawfish contained an average of 0.85 salmonids.fish-'. Sampling in John Day reservoir also coincided with high passage of juvenile salmonids at McNary and John Day dams (Figure 9).

Catches of northern squawfish were highest in BRZs similar to previous years (Petersen et al. 1990, 1991). Also, relatively high numbers of northern squawfish were captured in the upper locations of Lower Granite reservoir and the free-flowing Rogersburg location (Table 1). Sampling of these locations coincided with hatchery releases from the Clearwater, Salmon, and Grande Ronde rivers and it was possible northern squawfish were congregating in these areas due to high preyfish densities. However, CIs for northern squawfish were moderate (0.3-0.8) compared to other Snake River locations. Catches of northern squawfish (and other predators) also increased during turbid conditions at several locations. Kirkland (1962) attributed increased catch rates during high turbidity to decreased visual acuity, which allows electrofisher units to approach closer without detection by fish. Attenuated light could also promote nocturnal feeding of certain fishes (e.g. ictalurids) and cause them to move into shore to feed during the day (Moyle and Cech 1988) or cause sight-oriented fishes to move away from substrate (Gradell and Swenson 1982) possibly making them more susceptible to capture by electrofishing. Consumption index values for northern squawfish were lower during the period of high turbidity. Zaret (1979) noted that sight feeding predators exhibit a decrease in feeding efficiency during periods of high turbidity, which may account for the low CI values during these conditions. Also, shorter predator reactive distance to prey and fewer encounters between

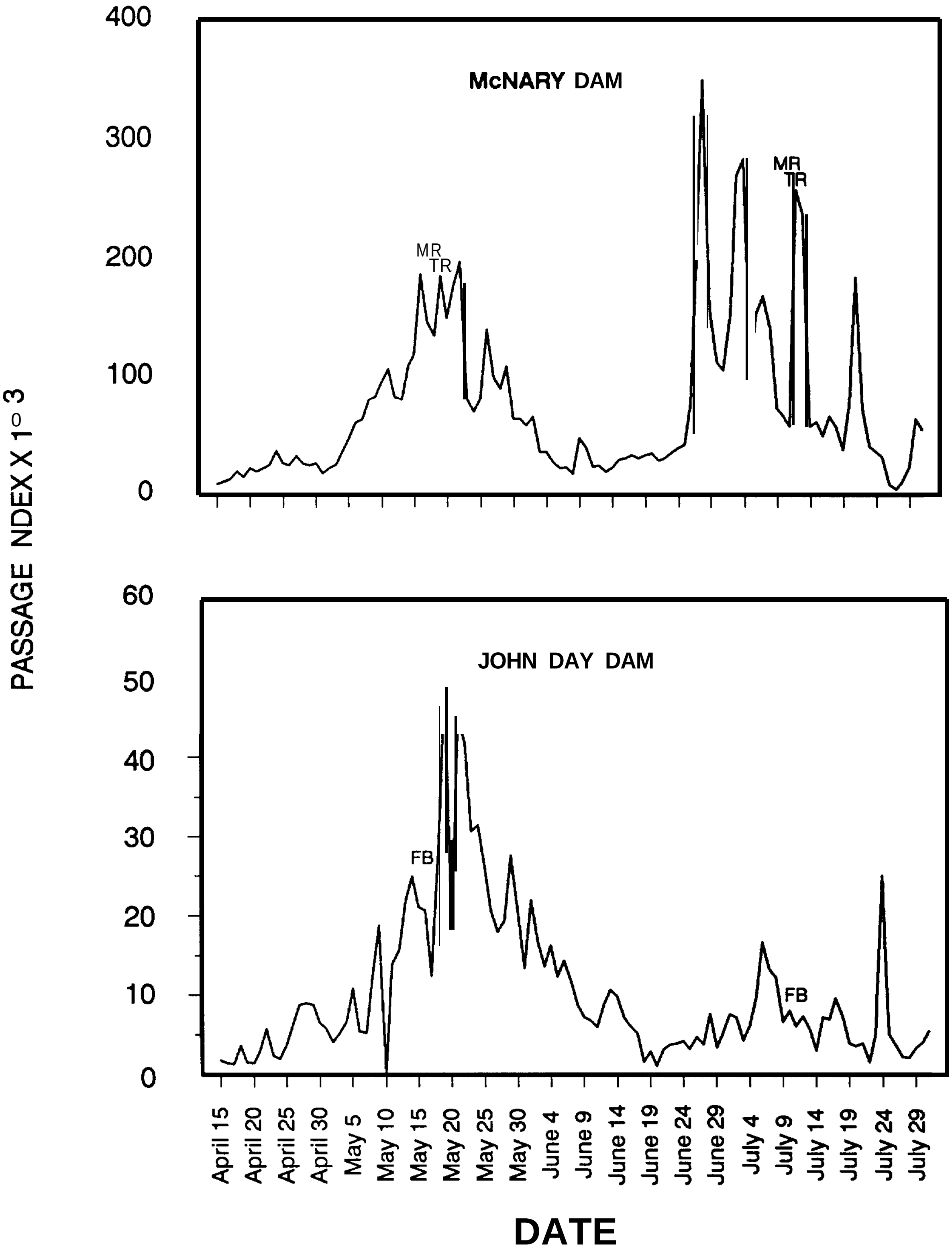

Figure 9. Timing of Consumption Index sampling during 1991 with respect to juvenile salmonid passage indices at John Day and McNary Dams. See Figure 8 for an explanation of notation.

predator and prey could contribute to a decrease in CI values (Vinyard and O'Brien 1976).

Smallmouth bass accounted for 41% of our total catch (Table 2). However, our data suggest the smallmouth bass predation on out-migrating salmonids was low. Tabor et al. (MS) reported smallmouth bass consumption rates to be relatively high (0.9 to 1.3 $salmonids \cdot fish^{-1} \cdot day^{-1}$) on recently emerged chinook salmon near the Hanford reach of the Columbia River. We estimated smallmouth bass mean consumption rate of salmonids to be much lower (0.01 $salmonids \cdot fish^{-1} \cdot day^{-1}$) at Snake River locations. The lower consumption rates at Snake River locations may be due to several factors: 1) the majority of salmonids migrating at the time of our sampling were juvenile spring chinook salmon and steelhead which may not be as susceptible as subyearling chinook salmon to predation by smallmouth bass due to size and habitat selection; 2) water temperatures were lower at Snake River locations than in the Hanford reach and therefore smallmouth bass may not be as actively feeding and; 3) there could be a difference in prey densities and alternative prey available between the two areas.

Bioenergetic Modeling

Results of the northern squawfish scale analyses suggest that large numbers (>50 per age group) of aged northern squawfish would be necessary to detect expected seasonal growth in predators ≥9 years; smaller samples (<20) would be needed to detect seasonal growth in younger, fast-growing predators. Large samples would be necessary to ensure that an adequate number of scales were available in each cohort. These conclusions prompted us to explore alternative methods for determining seasonal growth of northern squawfish in reservoirs, particularly the use of length or weight frequency distributions.

An alternative method to determine age-specific growth may be needed before the northern squawfish bioenergetics model can be applied to broad-scale questions about consumption rate and loss. An obvious approach to this problem is to use length or weight distributions and consider how these distributions change through a season. Consumption has been shown to vary with weight (Vigg et al. 1991; Petersen and DeAngelis, MS), suggesting that size, rather than age, may be a better indicator of potential feeding rate. Also, length or weight data are much easier to gather and would be available from several sources (predation indexing, dam angling, sport bounty fishing, etc.).

A typical weight distribution from a northern squawfish population represents individuals of a broad age range, roughly 4-15 years of age. Size-at-age may vary greatly so three individuals with the same weight might belong to three different age cohorts (Rieman and Beamesderfer 1988). Cohort peaks cannot be distinguished in such a distribution because of variable growth rates and, perhaps, variable spawning dates within a year (May to August or later). Two approaches for using size-frequency data are suggested below: 1) mean weight change for all sampled predators (similar to the "average predator" concept used by Poe et al. (1991) and Vigg et al. (1991)); and 2) weight change of fractions of a size distribution by using percentiles.

Cochran and Knutsen (1988) showed the true mean rate of food intake can be accurately estimated with a bioenergetic model using changes in mean body mass. They simulated growth of largemouth bass (Micropterus salmoides) and compared predicted and observed rates of consumption. Model-predicted consumption rates differed negligibly (<3.5%) from actual rates in all comparisons, except when extreme size-selective mortality or gear bias was introduced. However, comparisons were for a relatively narrow range of weights - maximum range for their "large" fish group was 160-240 g starting weight. Data from John Day Reservoir and McNary tailrace indicate that changes in mean weight can be detected by relatively small field samples. Typical northern squawfish appear to lose weight during spring through early summer and do not begin to gain weight until fall, when water temperatures are quite high. These observed patterns of weight change generally agree with earlier attempts to predict seasonal growth using a bioenergetic model (Petersen et al. 1990).

Use of mean weights for seasonal growth analysis requires assumptions about normality of predator sizes and the lack of a size effect upon feeding rate. As might be expected, even large monthly samples of fish from the river are non-normally distributed (unpublished Fish and Wildlife Service data). Other studies have shown a size-related feeding response, with larger predators capable of eating many more salmonids than small predators (Vigg et al. 1991; Petersen and DeAngelis, MS). Violation of these assumptions suggests the need for a more refined analysis of seasonal growth.

An alternative method for describing weight change would be to use the percentiles of frequency distributions of weight and examine how these percentile markers shift over a period of time when we expect growth. Equally-spaced percentiles (e.g., 10th, 20th, 30th . ..) would represent equal-sized parts of a distribution. Just as the weight of the average individual should increase with time, equivalent percentiles should also increase toward larger weights, providing there was growth in some or all of the population. This approach would be most helpful when size distributions change shape during a growing season, as when small predators grow much faster than large predators. The nonlinear relationship between size and predation rate (Petersen and DeAngelis, MS) could interact with size-specific seasonal growth to produce losses not easily predictable using a single size statistic, such as mean individual weight.

Several (n) percentile "cohorts" could be modeled and the predicted capture rate (salmonids$\cdot$fish$^{-1}\cdot$day^{-1}) could be estimated for each representative percentile. The mean population capture rate would be the percentile captures summed/n; each percentile capture rate would represent an equal proportion of the population as long as percentiles were equally spaced, so no weighting would be necessary.

Bioenergetic modeling work will proceed in three areas: 1) Parameters for the northern squawfish model will be reviewed and updated. In particular, recently estimated respiration parameters for northern squawfish (Cech et al. MS) will be incorporated into the model. 2) The possibility of using northern squawfish age-growth information from ODFW and Washington Department of Wildlife (WDW) will be explored. ODFW and WDW plan to age large numbers of northern squawfish during the coming years as part of the evaluation of the predator removal program. Some of these data may be appropriate for bioenergetic studies. 3) Methods for using size-frequency distributions to estimate seasonal growth will be further developed and explored. Model-predicted consumption rates will be compared to field estimates using the 1983-86 predator-prey data set.

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APPENDIX A

1990 Revised Consumption Index Results

Table A-l. Revised (i.e. without "gorp"; see Petersen et al 1990 for explanation) northern squawfish consumption indices (CI) at locations in the lower Columbia and Snake Rivers during 1990. Note that a single 0 means no juvenile salmonids were found in the predator guts. CI is the consumption index for the original sample (N). Mean CI, standard deviation (SD), coefficient of variation (CV, %) and quartiles are given for the 500 bootstrap samples. Tr=Tailrace, Fb=Forebay, Mr=mid-reservoir, Up=Upper reservoir.

RESERVOIR Location		N	CI	Mean	Bootstrap Summary SD	CV	Quartiles 25th	75th
SPRING								
Bonneville	Tr	150	2.1	2.2	0.4	18	1.9	2.4
BONNEVILLE								
Bonneville	Fb	153	0.6	0.6	0.2	33	0.5	0.8
Bonneville	Mr	39	0	0	0	--		0
The Dalles	Tr	48	1.6	1.7	0.3	18	1.x	1.9
THE DALLES								
The Dalles	Fb	38	0.8	0.8	0.2	25	0.7	0.9
The Dalles	Mr	15	0	0	0	--	0	0
John Day	Tr	77	0.9	0.9	0.1	11	0.8	0.9
JOHN DAY								
John Day	Fb	38	1.5	1.5	0.2	13	1.3	0.6
John Day	Mr	6	0	0	0	--	0	0
McNary	Tr	77	2.3	2.3	0.2	9	2.2	2.5
MCNARY								
McNary	Fb	24	1.3	1.4	0.3	21	1.2	1.6
McNary	Mr	9	0.1	0.1	0.1	100	0.0	0.2
McNary	Up	33	1.5	1.6	0.7	44	1.1	2.0
Ice Harbor	Tr	14	2.4	2.5	0.5	20	2.2	2.8
SUMMER								
Bonneville	Tr	154	4.7	4.8	1.0	21	4.1	5.4
BONNEVILLE								
Bonneville	Fb	139	1.8	1.8	0.7	39	1.3	2.2
Bonneville	Mr	42	0	0	0	--	0	0
The Dalles	Tr	67	0.7	0.7	0.4	57	0.5	0.9
THE DALLES								
The Dalles	Fb	61	1.0	1.0	0.5	50	0.6	1.4
The Dalles	Mr	51	0.1	1.0	1.1	110	0.0	1.6
John Day	Tr	96	4.3	4.3	0.7	16	3.9	4.8
JOHN DAY								
John Day	Fb	16	2.4	3.2	2.4	75	1.3	4.8
John Day	Mr	7	0.9	1.1	1.1	100	0.0	1.6
McNary	Tr	75	8.0	8.2	1.4	17	7.2	9.1
MCNARY								
McNary	Fb	9	2.4	2.5	1.3	52	1.6	3.4
McNary	Mr	14	1.8	1.9	0.9	47	1.2	2.4
McNary	Up	36	1.5	1.6	0.5	31	1.2	1.9
Ice Harbor	Tr	112	0.6	0.7	0.4	57	0.3	0.9

Table A-2. Revised Consumption indices (CI) of northern squawfish within dam BRZs in the lower Columbia and Snake Rivers during 1990. See Table A-l for explanation of columns.

RESERVOIR Location (BRZ only)	N	CI	Mean	Bootstrap Summary SD	CV	Quartiles 25th	75th
SPRING							
Bonneville Tr	89	2.2	2.7	0.3	11	2.4	2.9
BONNEVILLE							
Bonneville Fb	102	0.9	0.9	0.2	22	0.8	1.1
The Dalles Tr	41	2.3	2.4	0.3	12	2.2	2.6
THE DALLES							
The Dalles Fb	21	1.2	1.2	0.3	25	1.0	1.4
John Day Tr	50	0.9	0.9	0.1	11	0.8	1.0
JOHN DAY							
John Day Fb	34	1.5	1.5	0.2	13	1.3	1.6
McNary Tr	60	2.5	2.5	0.2	8	2.4	2.6
MCNARY							
McNary Fb	17	1.6	1.7	0.3	18	1.4	1.9
Ice Harbor Tr	14	2.4	2.4	0.5	21	2.1	2.7
SUMMER							
Bonneville Tr	109	5.5	5.4	1.1	20	4.7	6.1
BONNEVILLE							
Bonneville Fb	89	2.4	2.3	0.7	30	1.9	2.8
The Dalles Tr	63	0.8	0.9	0.5	55	0.5	1.1
THE DALLES							
The Dalles Fb	25	3.1	3.2	1.4	44	2.2	4.1
John Day Tr	50	6.4	6.5	0.6	9	6.0	6.9
JOHN DAY							
John Day Fb	11	2.9	4.0	3.2	80	1.6	5.8
McNary Tr	50	11.7	11.8	1.0	8	11.2	12.6
McNary Fb	8	2.5	2.6	1.3	50	1.7	3.3
Ice Harbor Tr	79	0.9	1.0	0.5	50	0.6	1.3

Table A-3. Revised Reservoir-wide (excluding BRZs at dams) CIs of northern squawfish during 1990 sampling in the lower Columbia and Snake Rivers. See Table A-l for explanation of columns.

RESERVOIR (excluding BRZ's)	N	CI	Mean	SD	CV	Bootstrap Summerv Ouartiles 25th	75th
SPRING							
BONNEVILLE	58	0.0	0.1	0.1	86	0.0	0.1
THE DALLES	27	0 4	0.4	0.1	36	0.3	0.5
JOHN DAY		1.3	1.4	0.4	27	1.1	1.6
MCNARY	49	1.0	1.0	0.4	38	0.7	1.3
SUMMER							
BONNEVILLE	96	0	0	0	-	0	0
THE DALLES	133	0.1	0.1	0.1	100	0.2	0.2
JOHN DAY	37	2.2	2.3	1.2			
MCNARY	84	1.2	1.2	0.4	33 52	1.4 1.0	3.1 1.5